4. COLLECTING, TRANSFERRING, AND MANAGING TIME-RELEVANT WATER QUALITY DATA

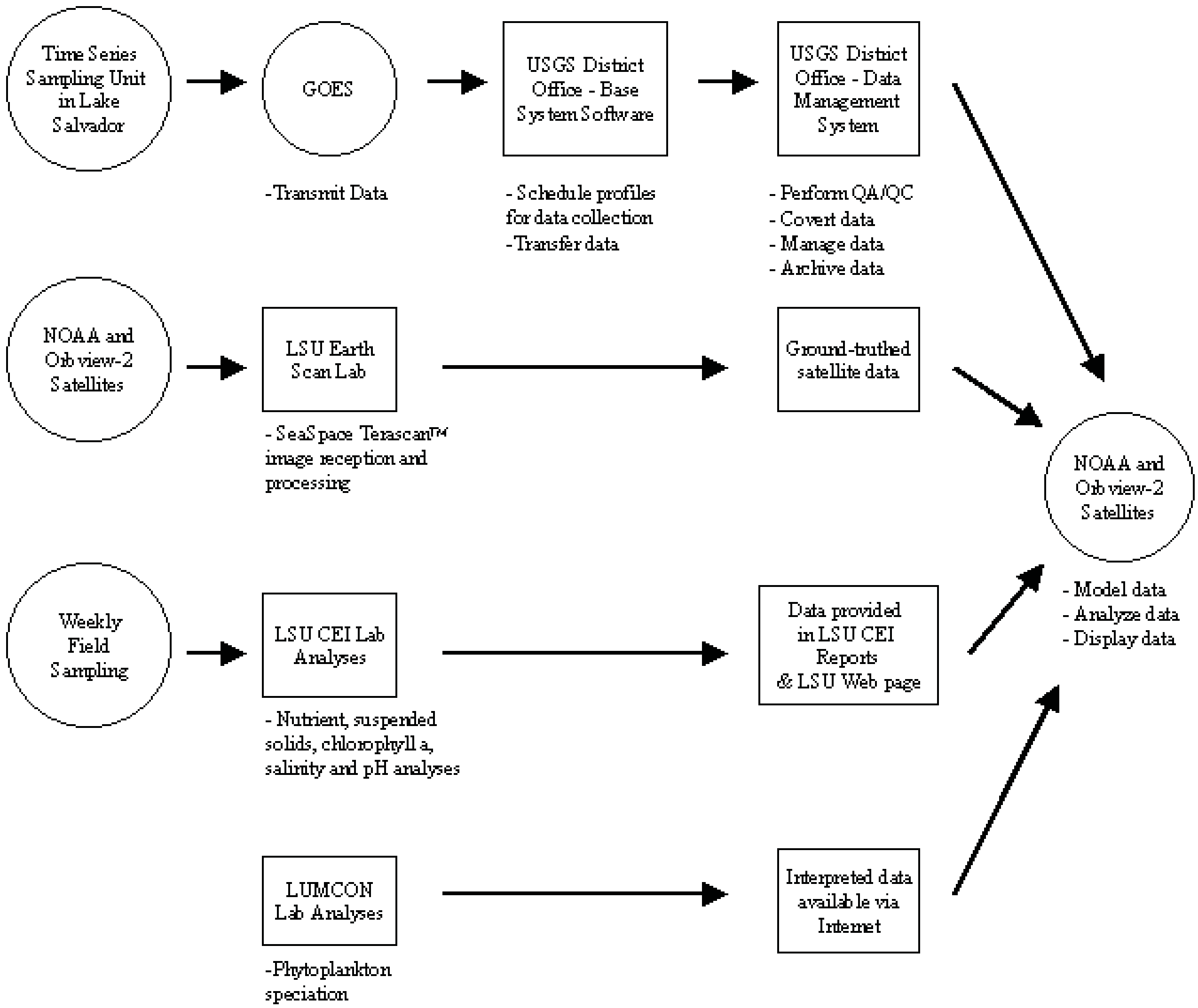
In order to effectively assess water quality and the impacts of water quality management activities, such as river diversions into estuaries, it is necessary to monitor water quality over time (i.e., monitor pre- and post-diversion water quality). The water quality monitoring should take into account water quality parameters important to the local community. Conducting a comprehensive manual sampling program that covers different times of the day, as well as different seasons and seasonal events, presents distinct challenges. As a result, many water quality monitoring programs, such as the Jefferson Parish Project, rely on automated systems, in which water sampling units collect data at programmed intervals and then transmit the data to a land-based station for storage, retrieval, and analysis. In addition, the Jefferson Parish project relies on remote sensing data to monitor water parameters. However, limited field sampling still has to be conducted to "surface truth" the satellite data.

Using the Jefferson Parish Project as a model, this chapter provides you and your community with "how-to" instructions on how to operate and maintain such data collection systems. If you are responsible for or interested in implementing time-series water sampling, you should carefully read the technical information presented in Section 4.2, which discusses setting up and using a sampling station for data collection and transfer, and managing the data at the base station. If you are interested in using remote sensing technology to monitor water quality parameters, you should read the information presented in the Section 4.3. This section provides detailed information on satellite data acquisition, processing, interpretation, ground-truthing, and data transfer and management. Details on water quality field sampling are discussed in Section 4.4, which provides details on sampling, water quality parameter analyses phytoplankton speciation, and data transfer and management. Readers interested in an overview of the system should focus primarily on the introductory information in Section 4.1 below.

4.1 System Overview

The water quality monitoring program for the Jefferson Parish Project uses three types of data: (1) time-series water sampling data; (2) satellite data; and (3) water quality field sampling data. The data are collected and analyzed by four separate entities. Time-series water sampling data and satellite data can be accessed through links from the Jefferson Parish Web site at http://www.jeffparish.net/pages/index.cfm?DocID=1228.

Figure 4.1 System Overview



The field sampling data are available via the Internet at http://its2.ocs.lsu.edu/guests/ceilc/. A schematic of the main components of the data collection, transfer, and management system for the Jefferson Parish project is presented in the figure on the following page.

The time-series water sampling data are collected by an automated system, in which a sampling unit collects hourly data and then transmits the data via GOES to the USGS District Office every four hours for storage, retrieval, and analysis. The sampling unit is located in Lake Salvador, a key outfall area of the Davis Pond Freshwater Diversion Project.

Satellite data collected by NOAA satellites are received and processed using SeaSpace Terascan™ system which operates at the Earth Scan Laboratory, Coastal Studies Institute at LSU. This software package performs calibration, geometric correction, and more specialized processing for the determination of temperature, reflectance (turbidity), and chlorophyll *a* concentrations. Water sampling results are used to "surface truth" satellite reflectance measurements and to relate the digital measurements of turbidity and fluorescence to suspended solids and chlorophyll *a*.

Water quality field sampling is conducted weekly from seven stations in Lake Salvador and Lake Cataouche (a smaller lake north of Lake Salvador) to ground-truth remote sensing data and validate time-series water sampling data. The LSU-CEI analyzes the samples for chlorophyll *a*, nutrients, and suspended solids. The LUMCON provides data on phytoplankton speciation including identification of harmful algal species. The field sampling data are interpreted and made available via the Internet.

4.2 Time-Series Water Quality Sampling

A data collection, transfer, and management system can benefit your community in two ways: It enables you to automate the collection of water quality samples, and it enables you to control the resulting data flexibly and easily. By using the system's software, you can program your time-series water sampling unit to collect water quality data at specified intervals. Then you can call the sampling unit as needed for data transmission or program your system to call for transmissions of data at specified times. Once the data arrive, the information can be formatted and stored or otherwise prepared for export to another database, or it can be analyzed using geographical information system or data visualization software.

The sampling station unit is installed on a platform in the water and programmed to collect water quality data at specified intervals. The sampling unit has a multiprobe water quality sensor manufactured by YSI. This YSI Model 6600 data collection station is equipped with two optical ports for temperature and conductivity measurements plus a pressure and turbidity probe and dissolved oxygen and pH sensors. The data collected by the sampling station unit is transmitted via GOES to the USGS District Office at set time intervals and displayed on the USGS Internet home page. The data is archived as part of the USGS national hydrologic information system and resides in INGRES, a software developed by the USGS. Data security is managed by established USGS procedures.

The land-based station at the USGS District Office is basically a computer equipped with two main parts: (1) the base system software used to create profile schedules of sampling parameters and to communicate with the sampling station unit to transmit schedules and receive sampling data and (2) the database management system used to format, quality check, and store collected data.

The sampling station unit and the base station computer are equipped with communications hardware featuring a satellite radio transmitter. This equipment allows the sampling station unit and computer to "talk" to each other over long distances. Because of this communication ability, the sampling station unit becomes part of a remote data acquisition system controlled from the land-base station. At the base station, an operator runs the sampling station-base software to connect to the sampling station unit for data collection and transfer.

The system's flexibility enables you to establish sampling and data transfer protocols based on your specific monitoring needs. For example, you might program your sampling station unit to sample every hour, 7 days a week, to monitor general trends. You might also want to conduct sampling specific to certain events, such as conditions conducive to algal blooms, during which you might monitor water quality on a 30-minute basis.

The system can collect and store data for future use, or it can retrieve and transmit collected data in near-real time. Each sampling station unit stores collected data in its on-board computer, making the data available for download on demand by the base station. The unit can also serve as a temporary archive by retaining a copy of all transmitted data files. Once the unit runs out of space, it will overwrite data as necessary, beginning with the oldest data.

The remainder of this section provides information on how the data collected by the sampling system are transferred to the base station, how the data are managed, and which troubleshooting and data quality assurance steps are taken. These steps are illustrated using the Jefferson Parish project as an example.

How often should data be collected?

The Jefferson Parish time-series sampling station collects samples on an hourly basis and transmits the data via GOES to the USGS District Office every four hours. The data is then displayed on the USGS Internet home page.

4.2.1 Data Collection Equipment Calibration

USGS members of the Jefferson Parish team perform routine, weekly maintenance and calibration of the sensors with independent equipment. This independent equipment is tested to ensure accuracy and reliability of the field instrumentation. The USGS district office ensures that adequate testing is carried out and the documented results fully characterize the performance and capabilities of the instruments. The USGS Hydrologic Instrumentation Facility (HIF) conducts testing, evaluation, and documentation of instrument performance. USGS districts purchase instruments through HIF when possible. HIF can also perform independent testing for the district offices. The USGS Web site (http://water.usgs.gov/pubs/wri/wri004252/#pdf) is a good source for background information on calibration and data QA/QC of "real-time" water quality monitoring systems. Table 4.1 shows some USGS sensor calibration requirements. USGS recommends that equipment adjustments be made until the equipment meets their recommended calibration criteria. Otherwise, equipment that cannot meet the calibration criterial should be replaced. The information in this Section is summarized from the USGS document titled "Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Site Selection, Field Operation, Calibration, Record Computation, and Reporting" available from the USGS Web site listed above. The USGS guidelines referred to in this document have evolved based on decades of experience with water-quality monitoring.

4.2.2 Transferring Your Collected Data to the Base Station

As a first step, you will need to determine what kind of data communication or telemetry equipment to install on your sampling station unit. Telemetry equipment enables data to be transferred from a sampling station to a receiving station (i.e., the base station). You can choose between a number of telemetry equipment options including cellular telephone modem, a 900 MHz transceiver, and a satellite radio transmitter.

Jefferson Parish Telemetry Equipment

The USGS, a key partner in the Jefferson Parish EMPACT project, uses automated earth-satellite telemetry for the transmission of data via satellite from the time-series sampling system located in lake Salvador. The data are being collected on an hourly basis and transmitted via GOES. Every four hours a data set that consist of eight hours of monitoring data are being transmitted (one redundant data set from the past four hours and one current four hour data set).

Table 4.1. Sensor Calibration and Accuracy Requirements

Sensor	USGS-Recommended Calibration Accuracy	Calibration
Temperature	+/- 0.2°C	Annual 5-point calibration over temperature range of 0-40°C. Three or more 2-point calibration checks per year for thermistors over the maximum and minimum expected temperature range.
Dissolved Oxygen	+/- 0.3 mg/L	Calibration is conducted weekly at 0.0 mg/L and 100% dissolved oxygen saturation.
Specific Conductance	The greater of +/- 5 uS/cm or +/- 3 % of the measured value	Standards bracketing the expected full range are used to calibrate the specific meter to the appropriate units for particular field conditions. The specific conductance standards are available from the USGS Ocala Quality Water Service Unit (QWSU).
pH	` 0.2 pH units	Two standard buffers bracketing the expected range of values are used to calibrate the PH electrode, and a third is used to check for linearity. The pH-7 buffer is used to establish the null point, and the pH-4 or pH-10 buffer is used to establish the slope of the calibration line at the temperature of the solution. The temperatures of the buffers should be as close as possible to the samples being measured. Standard buffers are available from QWSU.
Turbidity	The greater of +/- 5 NTU or +/- 5 % of the measured value	Conduct 3 point calibration at values of 0, 10, and 100 NTU using standards based on either Formazin or approved primary standards, such as styrene divinylbenzene polymer standards.

The access to GOES to transmit information is limited to specified users such as governmental agencies like USGS or the Corps of Engineers. Thus, if you want to use satellite telemetry to transmit your data from the sampling system to the base station, you may want to enter into a cooperative agreement with an organization such as USGS.

The GOES are operated by the NESDIS of NOAA. The GOES Satellite Radio Module consists of a 10-watt transmitter that can be set to any of the allowable 199 domestic GOES and 33 international channels assigned by NESDIS. The normal configuration of GOES consists of the GOES East The normal configuration of GOES consists of the GOES East satellite stationed 21,700 miles above the equator at 75 degrees west longitude and the GOES West satellite is at 135 degrees west longitude.

Data are transmitted by the data acquisition system on an assigned UHF-band frequency in the direction of the GOES. The GOES repeats the message in the S-band, which is received at the NESDIS ground station at Wallops Island, Virginia. The data are then re-broadcast to the DOMSAT satellite, which is a low orbiting communications satellite, and then retrieved on an eight-foot dish at the USGS office in Baton Rouge. A schematic of the data transfer process is shown in Figure 4.2.

4.2.3 Managing Data at the Base Station

This section provides you with background information on managing data at the base station. It discusses the basic data management steps conducted at the base station including processing, QA/QC, distribution, and storage.

The base station software used by USGS is called ILEX, which is a specialized software that was developed specifically for USGS by an outside contractor. The Local Readout Ground Station (LRGS) at the USGS district office in Baton Rouge receives data from all USGS data collection sites. By entering specific site codes, data from specific USGS monitoring sites can be filtered out and kept for processing.

The data received by the LRGS are processed, checked to assure they do not fall outside the range of set thresholds, and distributed. The data are stored/archived as part of the USGS national hydrologic information system and resides in INGRES, a software developed by USGS. Data security is managed by established USGS procedures. USGS is currently coordinating with the EPA to make the archived data available in STORET, a software used by the EPA. The data are displayed near-real time on the USGS Hydrowatch Web site, from where they can be accessed by anyone who has access to the Internet including Federal, State, and local agencies, academia, industry, the public, policy-makers, and managers. Figure 4.3 shows the data transfer to the base station and the basic data management steps taken at the base station.

Data-Processing Procedures

To ensure time-relevant access to the data and to avoid data management problems, the water quality monitoring data should be processed soon after data collection and retrieval. When processing the data, no corrections should be made unless they can be validated or explained with information or observations in the field notes or by comparison to information from other data sources. The USGS data processing procedures consist of six major steps: (1) initial data evaluation, (2) application of corrections and shifts, (3) application and evaluation of cross-section corrections, (4) final data evaluation, (5) record checking, and (6) record review. These processing procedures, which are described in detail in the sections below, are summarized from the USGS document titled "Guidelines and

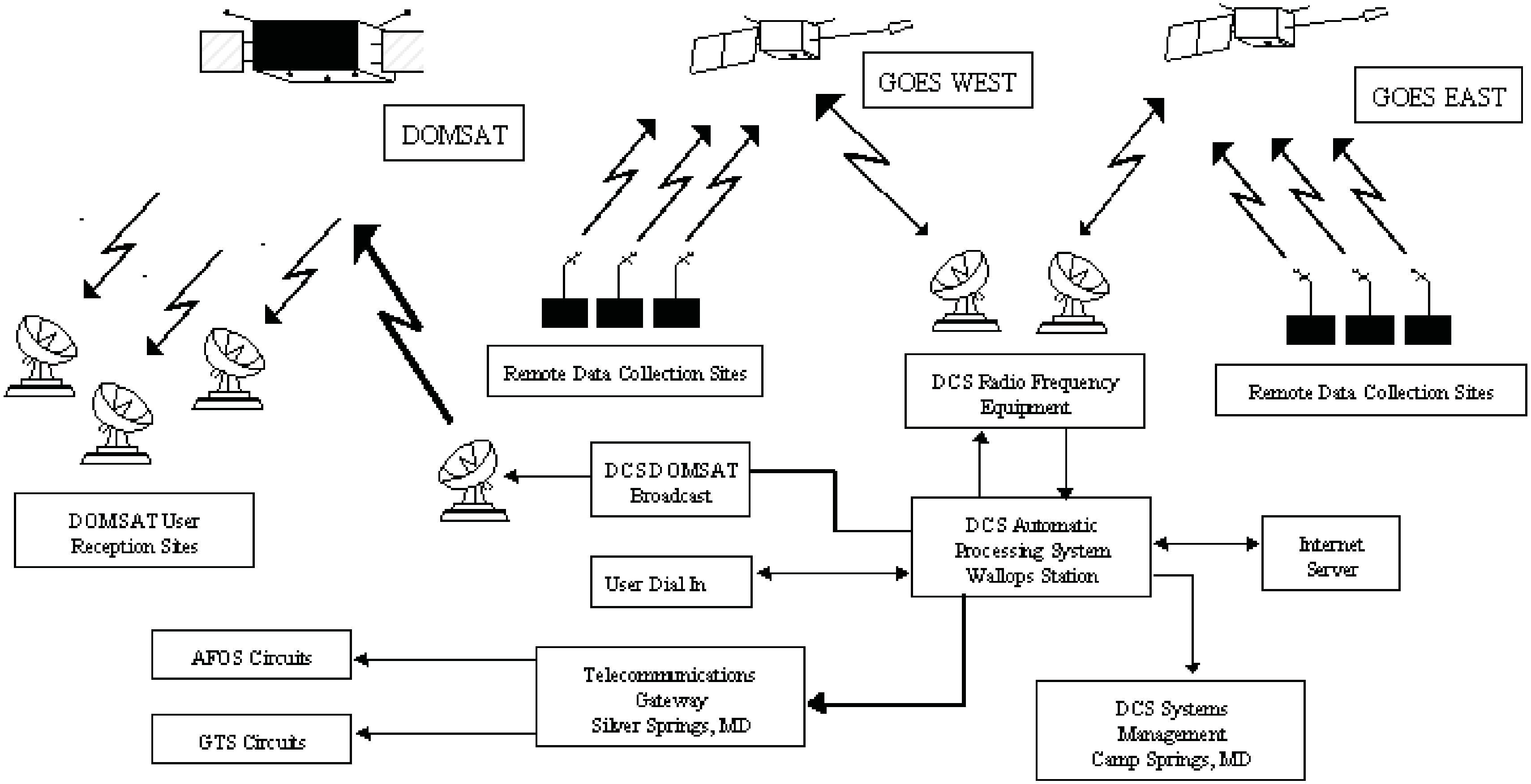
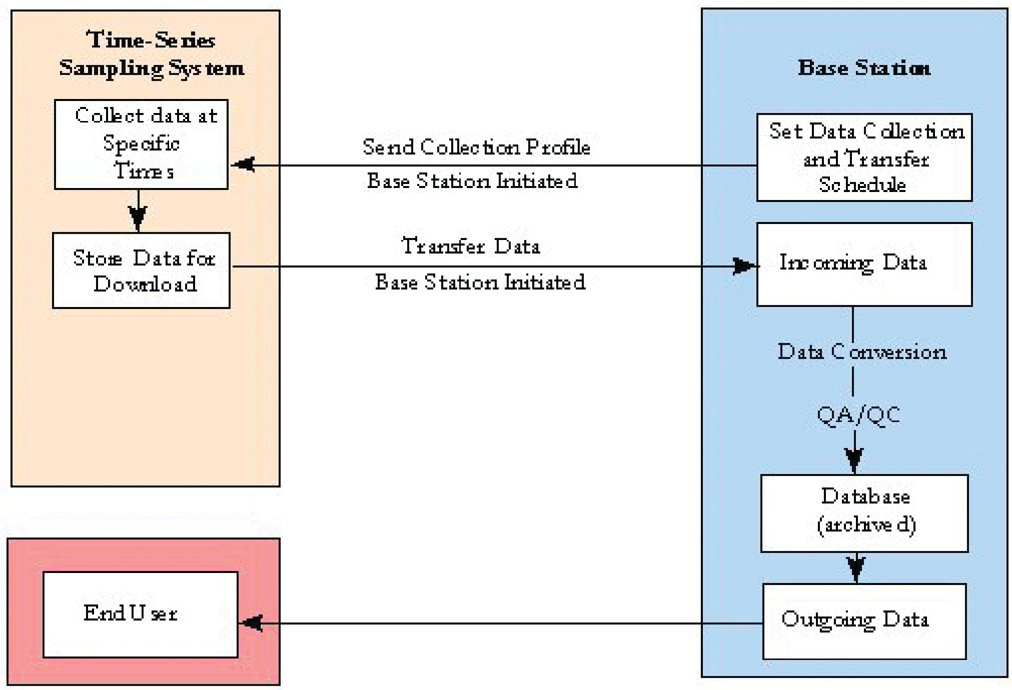


Figure 4.2 Schematic of the GOES DATA Collection System (DCS) and Data Transfer Process
Source: http://www.osd.noaa.gov/sats/dcs/dcs-figure.htm

Figure 4.3. Data Transfer and Management Diagram



Standard Procedures for Continuous Water-Quality Monitors: Site Selection, Field Operation, Calibration, Record Computation, and Reporting" available from the USGS Web site at http://water.usgs.gov/pubs/wri/wri004252/#pdf.

Initial Data Evaluation

In the initial data evaluation step, USGS checks the success of the raw field data transfer to the office database. This provides an opportunity for initial checks to evaluate and correct erroneous data. The raw field data may be stored in a variety of formats, depending on the recording equipment and the means of downloading data from the recording equipment. The conversion of raw data from the sampling system into a standard entry format to the USGS district database, or Automated Data-Processing System (ADAPS), is accomplished by using an on-line computer program, or Device Conversion and Delivery System (DECODES). After entry into ADAPS, primary data tables and plots can be produced for review.

Application of Corrections and Shifts

The application of corrections and shifts allows USGS to adjust data to compensate for errors that occurred during the service interval as a result of environmental or instrumental effects. There are three types of measurement-error corrections: (1) fouling, (2) drift, and (3) cross-section correction. USGS only make corrections to measurements when the type and degree of correction is known. If the deviation between the actual value and sensor reading exceed the criterion for water quality data shifts, as shown in Table 4.2, a correction is required. The correction is a linear interpolation over time between sensor inspections.

Table 4.2. Criteria for Water-Quality Data Shifts

Measured Physical Property	USGS-Recommended Shift Criteria (Apply Shift when Deviation Exceeds this Value)
Temperature	+/- 0.2°C
Dissolved Oxygen	+/- 0.3 mg/L
Specific Conductance	The greater of +/- 5 uS/cm or +/- 3 % of the measured value
pH	` 0.2 pH units
Turbidity	The greater of +/- 5 NTU or +/- 5 % of the measured value

Evaluation and Application of Cross-Section Corrections

Cross-section corrections allow USGS to adjust measurements of the monitoring equipment to reflect conditions more accurately in the entire cross section of the monitoring area (e.g., from bank to bank of the water body that you are monitoring). The application of cross-section corrections is intended to improve the accuracy and representativeness of monitoring measurements. However, USGS only makes cross section corrections, if the variability in the cross section exceeds the shift criteria. Corrections to the cross section are based on field measurements taken both horizontally and vertically in the water body cross section.

Final Data Evaluation

Final data evaluations consist of reviewing the data record, checking shifts, and making any needed final corrections. When completed, USGS verifies the data for publication and rates the data for quality. The data that USGS cannot verify or that are rated as unacceptable are retained for record-checking and review purposes but are not published in ADAPS. However, USGS archives unacceptable or unverified data following established USGS district policies.

Many USGS district offices have established quality-control limits for shifting data, which are commonly referred to as "maximum allowable limits." This means that data are not published, if the recorded values differ from the field-measured values by more than the maximum allowable limits. For the purpose of consistency within the USGS the limits are established at 10 times the calibration criteria for all standard continuous-monitoring data-gathering activities, except for more stringent requirements for DO and turbidity. Table 4.3 below shows the maximum allowable limits for continuous water quality monitoring sensors.

Table 4.3. USGS Recommended Maximum Allowable Limits for Continuous Water-Quality Monitoring Sensors

Measured Physical Property	Maximum Allowable Limits for Water Quality Sensor Values
Temperature	+/- 2.0°C
Dissolved Oxygen	The greater of +/- 2.0 mg/L or 20 %
Specific Conductance	+/- 30 %
pH	□2.0 pH units
Turbidity	+/- 30 %

After evaluating each record for maximum allowable limits, USGS applies one of four accuracy classifications to each measured physical property on a scale ranging from poor to excellent. The accuracy ratings are based on data values recorded before any shifts or corrections are made and depend on how much the recorded values differ from the field-measured values. For more details on the USGS data publication criteria guidelines refer to the USGS document titled "Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Site Selection, Field Operation, Calibration, Record Computation, and Reporting" available from the USGS Web site at http://water.usgs.gov/pubs/wri/wri004252/#pdf.

Record Checking and Record Review

In the record checking process, USGS thoroughly checks all data used in producing the final water quality record for completeness and accuracy before final review and publication. The hydrographer who is responsible for computing the water quality record first reviews the record, followed by a second check for completeness and accuracy by an experienced hydrographer. Finally, the USGS district water quality specialist or district-designated reviewer inspects the water quality record. In addition, all field data are verified for accuracy and transcription from field sheets, all shifts are checked to assure that the correct values are used for a shift, and all dates and numbers in the station manuscript are checked for accuracy.

Near-Real Time Data QA/QC versus Non-Real Time Data QA/QC

Depending on the type of data (near-real time versus non-real time data) you are providing to the public, you can spend different amounts of time and effort on quality control checks. If your goal is to provide near-real time data, there is no time for extensive manual QA/QC checks. On the other hand, if you are providing non-real time data, you have time to perform extensive quality checks, as described in the sections above. Performing quality checks on Jefferson Parish non-real time data can take from a few days to weeks or months, depending on the amount of data streaming into the project's base station.

When you are providing near-real time data, such as the data found on the USGS Hydrowatch Web site, time for QA/QC checks is limited. The checks that can be conducted must either be automated or can only focus on obvious data problems, if they are done manually. The near-real time data undergo two very basic QA/QC steps during the data management process.

The first QA/QC step is done while the data are processed by the DECODES software program at the USGS base station. USGS can enter set thresholds in the DECODES software for each water quality parameter. If the value for any given parameter falls outside the acceptable range entered for that parameter, the data point will be removed. For example, if a pH reading exceeding a pH of 10 is recorded, the data point will be removed because it falls in an unacceptable range for that particular parameter.

The second QA/QC step is taken at the base station when the data are imported into Microsoft Access. At this point, the data undergo a brief manual QA/QC step, at which outliers or obvious erroneous data points are deleted manually from the database.

Storing and Archiving the Data

It is recommended that you store and archive all sample records, raw data, quality control data, and results. A variety of media are available for archiving data (e. g., CD- ROMs, Zip disks, floppy diskettes, and hard copy). The server storing the data should also be backed up daily to prevent data loss.

4.2.4 Troubleshooting

This section contains information about common troubleshooting issues. Table 4.4 below can be used to identify the causes of some common difficulties that may occur while operating the YSI 6600 sensor package. The "symptom" column describes the type of difficulty that you might experience, the "possible cause" column describes the condition that might cause the stated symptom, and the "action" column provides simple steps that can be followed to correct the problem. [Source: The user's manual for the YSI 6600 sensor package, which can be downloaded from the Yellow Springs Instruments, Inc. Web site at http://www.ysi.com

Table 4.4. Common Troubleshooting Issues and Actions

Symptoms	Possible Cause	Action
Dissolved Oxygen reading unstable or inaccurate	Probe not properly calibrated	Follow DO calibration procedures
	Membrane not properly installed or punctured	Follow setup procedure
	DO probe electrodes require cleaning	Follow DO cleaning procedure
	Water in probe connector	Dry connector; reinstall probe
	Algae or other contaminant clinging to probe	Rinse DO probe with clean water
	Barometric pressure is incorrect	Repeat DO calibration procedure
	Calibrated at extreme temperature	Recalibrate at/near sample temperature
	DO charge to high (>100): (1) Anode polarized (tarnished) (2) Probe left on continuously	Enable DO charge parameter in sonde report menu. Run sonde, if charge is over 100, recondition probe. Follow DO cleaning procedure.
	DO charge too low (<25); insufficient electrolyte.	Replace electrolyte and membrane
	DO probe has been damaged	Replace probe
	Internal failure	Return sonde for service
pH, chloride, ammonium, or nitrate readings are unstable or inaccurate. Error messages appear during calibration.	Probe requires cleaning	Follow probe cleaning procedure
	Probe requires calibration	Follow calibration procedures
	pH probe reference junction has dried out from improper storage	Soak probe in tap water or buffer until readings become stable
	Water in probe connector	Dry connector; reinstall probe
	Probe has been damaged	Replace probe
	Calibration solutions out of spec or contaminated	Use new calibration solutions
	Internal failure	Return sonde for service
Level Sensor unstable or inaccurate	Desiccant is spent	Replace desiccant
	Level sensor hole is obstructed	Follow level sensor cleaning procedure
	Level sensor has been damaged	Return sonde for service
	Internal failure	Return sonde for service
Conductivity unstable or inaccurate. Error messages appear during calibration	Conductivity improperly calibrated	Follow recalibration procedure
	Conductivity probe requires cleaning	Follow cleaning procedure
	Conductivity probe damaged	Replace probe
	Calibration solution out of spec or contaminated	Use new calibration solution
	Internal failure	Return sonde for service
	Calibration solution or sample does not cover entire sensor	Immerse sensor fully

Table 4.4. Concluded - Common Troubleshooting Issues and Actions

Symptoms	Possible Cause	Action
Installed probe has no reading	Sensor has been disabled	Enable sensor
	Water in probe connector	Dry connector; reinstall probe
	Probe has been damaged	Replace probe
	Report output improperly set	Set up report output
	Internal failure	Return sonde for service
Temperature unstable or inaccurate	Water in connector	Dry connector; reinstall probe
	Probe has been damaged	Replace probe
Turbidity probe unstable or inaccurate. Error messages appear during calibration	Probe requires cleaning	Follow probe cleaning procedure
	Probe requires calibration	Follow calibration procedure
	Probe has been damaged	Replace probe
	Water in probe connector	Dry connector; reinstall probe
	Calibration solutions out of spec	Use new calibration solutions
	Wiper is not turning or is not synchronized	Activate wiper. Assure rotation. Make sure set screw is tight.
	Wiper is fouled or damaged	Clean or replace wiper
	Internal failure	Return probe for service

4.3 Satellite/Remote Sensing Technology

4.3.1 Data Acquisition

As mentioned earlier, LSU receives two different satellite data streams; NOAA AVHRR and Orbview-2 SeaWiFS. AVHRR satellite data are available to anyone who has the capability to receive it. NOAA does not charge any fee for an entity to establish and operate a station to receive AVHRR data nor does NOAA require station operators to make themselves known to NOAA. However, NOAA recommends that operators subscribe to NOAA's mail outs and make use of its on-line bulletin board. NOAA maintains an office to support potential operators of HRPT at the following address:

Coordinator, Direct Readout Services
NOAA/NESDIS
Washington, DC 20233

HRPT ground stations can be constructed using commercial equipment for under $100,000. However, some radio amateurs have constructed systems for $100s using personal computers, surplus antennas, and circuit boards.
[Source: http://www.ngdc.noaa.gov/seg/globsys/avhrr3.shtml]

If your project is not considered "research," the SeaWiFS data can be purchased from Orbimage, since they own the commercial rights to SeaWiFS. Note that Orbimage refers to SeaWiFS data as OrbView-2. If your project is considered research, you may apply to become a NASA-Authorized SeaWiFS user. To become an Authorized SeaWiFS data user, you must read the *SeaWiFS Dear Colleague Letter* and *Appendices* to gain an understanding of the terms of the user agreement. The applicant must then submit a short proposal, which includes the title of the project, a scientific rationale for the request, the processing level of the data required, and plans for the publication/dissemination of the results or data access. The applicant must print, sign, and complete a hard copy of the *Research Data Use Terms and Conditions Agreement*. The applicant must mail the proposal and original hard copy of the form to:

Dr. Charles R. McClain
SeaWiFS Project
NASA/GSFC Code 970.2
Building 28, Room W108
Greenbelt, MD 20771

Additional procedures for requesting data should be followed if the applicant desires to become an authorized SeaWiFS Direct Readout Ground Station or an authorized SeaWiFS Temporary Real-Time User or Station. There are not any specific deadlines for receipt of proposals to obtain SeaWiFS data. [Source: http://seawifs.gsfc.nasa.gov/SEAWIFS/ LICENSE/checklist.html]

Once approved as an authorized user, you can receive data for free from the Goddard Distributed Active Archive Center (DAAC) after the data is at least two weeks old. If your project is considered research and your organization wants to receive HRPT SeaWiFS data, you can apply to become an authorized SeaWiFS Ground Station. Current SeaWiFS users who want to get data in real-time from an existing SeaWiFS Ground Station, can apply to become an authorized SeaWiFS Temporary Real-Time User. [Source: http://seawifs.gsfc.nasa.gov./SEAWIFS/ ANNOUNCEMENTS/getting_data.html]

LSU is an authorized SeaWiFS Direct Readout Ground Station and has applied for and received authorization to become a Temporary Real-Time User Station. However, since the data must be held for two weeks prior to publication, the SeaWiFS data are not placed on the LSU Web site.

If a new user wants a turnkey operation to obtain SeaWiFS data, SeaSpace TeraScan SeaWiFS systems can be purchased. [Note that you must still obtain a decryption device and decryption key from NASA to read the data.] The TeraScan SeaWiFS system can be configured to support land-based, shipboard, or portable applications and is comprised of the following components:

- Polar Orbiting Tracking Antenna (1.2 m and 1.5 m)
- Global Positioning System (GPS) Antenna/Receiver
- Telemetry Receiver
- SGP Interface Unit (SGPI)
- Workstation
- Uninterruptible Power Supply (UPS)
- TeraScan Software

The specifications for the TeraScan SeaWiFS system are described below.

Antenna

Specifications	1.2 m Antenna	1.5 m Antenna
Reflector Diameter	1.2 m (4 ft)	1.5 m (5 ft)
Input Frequency	1691 - 1714 MHz	1691 - 1714 MHz
Acquisition Elevation	8 degrees	5 degrees
LNA Gain	30 dB minimum LNA Gain	30 dB minimum LNA Gain
LNA Noise Figure	<0.8 dB	<0.8 dB
Input Bandwidth	15 MHz	15 MHz
Downconverter Gain	22 dB minimum	22 dB minimum
Elevation Range	0 to 90 degrees	0 to 180 degrees
Azimuth Range	± 265 degrees	± 265 degrees
Elevation/Azimuth Tracking Rate	6 degrees per second	6 degrees per second
Position Accuracy	0.5 degrees	0.5 degrees
Temperature Range	-30°C (-22°F) - without heater to 70°C (158°F)	-30°C (-22°F) - without heater to 60°C (140°F)
Humidity	0 to 100%	0 to 100%
Maximum Wind Force	161 km/hr (100 mph)	161 km/hr (100 mph)
Radome Dimension	1.55 m (61") diameter by 1.67 m (65.90") high	1.88 m (73.88") diameter by 1.82 m (71.94") high
Antenna/Radome Weight	95 kg (210 lbs)	131 kg (290 lbs)
Antenna Shipping Weight	227 kg (500 lbs)	273 kg (600 lbs)

GPS

- Satellites tracked: 8
- Satellites used in a solution: 4
- Positional Accuracy: ±100 m (330 ft)
- System Time Accuracy: ± 0.1 second

Receiver

- Model: HR-250
- IF input frequency range: 128 - 145 MHz
- Demodulator Type: PSK-PLL

■ IF input frequency range:	128 - 145 MHz
■ Demodulator Type:	PSK-PLL
■ Bit rate:	665.4 Kbps
■ Bit error rate:	Within 1 db of theoretical

- Programmable IF input frequency selection

Workstation

■ Type:	Sun ULTRA-10
■ Processor:	440 MHz
■ Memory:	128 MB RAM
■ Internal Hard Drive Capacity:	18 GB
■ Internal CD-ROM Capacity:	644 MB
■ Monitor Size:	21"
■ Display Resolution:	1280 x 1024 x 24 bit
■ LAN Types:	10/100 BaseT
■ External DAT 4 mm Tape Storage:	24 GB compressed
■ Modem:	56 Kbps
■ Operating System:	Solaris 7

- Keyboard and mouse
- PCI Frame Synchronizer
- PCI SCSI Controller
- PCI Serial Multiplexer

UPS

- Output Power Capacity 1400 VA
- Dimensions: 0.18 m (7") W x 0.23 m (9") H x 0.42 m (18") D

Options

- Antenna Pedestal
- Antenna Heater
- Color Printer
- 100 m (330 ft) Antenna Control and Signal Cable

For more information about the TeraScan SeaWiFS system refer to their Web site, the source of this information, at http://www.seaspace.com/ main product_line/seawifs/seawifs.html.

4.3.2 Data Processing

Acquisition and processing of the satellite data are performed using the SeaSpace TeraScan™ image reception and processing system operated at the LSU Earth Scan Laboratory (http://www.esl.lsu.edu). This software performs calibration, geometric correction, and additional specialized processing for the determination of temperature, reflectance (turbidity), and chlorophyll *a*.

AVHRR - Dr. Nan Walker and Adele Hammack (LSU-CSI) view satellite imagery from the NOAA satellites daily (at least 8 times per day) and processes these images with specialized software to produce color-enhanced imagery of water temperature and turbidity (reflectance). At the end of each month, Dr. Walker provides a written description of the more interesting images taken during the month to assist the public in interpreting the turbidity and temperature changes that are visible in the satellite images.

For the EMPACT project, sea surface temperatures (SST) are computed, in either Celsius or Fahrenheit, with NOAA AVHRR satellite data using a modification of the MCSST technique described by McClain et al (1985). Surface reflectance is computed in percent albedo with NOAA AVHRR satellite data using a modification (Walker and Hammack, 2000) of the Stumpf atmospheric correction technique (1992). The technique corrects for incoming solar irradiance, aerosols, sunlight and Rayleigh scattering.

Dr. Walker uses a commercial software package suite called TeraScan™, which is produced by SeaSpace. You can find SeaSpace's Web site at http://www.seaspace.com. The TeraScan™ software suite includes software for data acquisition and scheduling called TeraCapCon and TeraTrack. TeraMaster & TeraPGS are used for product generation. TeraVision is used for developing images to visualize satellite data. TeraPGS is used to distribute data images according to user specifications. The image processing of temperature and reflectance is a multi-step process and is outlined below.

- Calibrate visible and thermal infrared data from count values to science units.
- Screen the data for image quality.
- Calculate temperatures and reflectances.
- Navigation/registration images to project on a rectangular map.
- Scale temperatures and reflectances.
- Produce GIF images of temperatures and reflectances.
- Post images on LSU Web site (http://www.esl.lsu.edu/research/empact.html).

[Source: EMPACT 1st Year Report, Satellite Remote Sensing of Surface Water Temperature, Surface Reflectance, and Chlorophyll a Concentrations: Southeastern Louisiana, Nan D. Walker, Adele Hammack, and Soe Myint, November 2000.]

SeaWiFS - The Orbview-2 satellite broadcasts SeaWiFS data in real time to the GSFC HRPT Station as well as other stations. LSU receives the SeaWiFS data in real-time via their satellite. LSU uses the SeaSpace TeraScan™ software suite to process (calibrate and atmospherically correct) and visualize the SeaWiFS data. The software is based upon the SeaDAS software used by NASA. The NASA OC2 algorithm is used to estimate chlorophyll *a* concentrations with the 490 and 555 nm bands (O'Reilly et al., 1998).

[Source: EMPACT 1st Year Report, Satellite Remote Sensing of Surface Water Temperature, Surface Reflectance, and Chlorophyll a Concentrations: Southeastern Louisiana, Nan D. Walker, Adele Hammack, and Soe Myint, November 2000.]

4.3.3 Data Interpretation

Wind measurements from monitoring stations are used to interpret the image patterns and to write the monthly text that is provided on the LSU Web site. The hourly time-series measurements at the Lake Salvador monitoring station are obtained from the USGS and used to interpret the satellite data.

[Source: EMPACT 1st Year Report, Satellite Remote Sensing of Surface Water Temperature, Surface Reflectance, and Chlorophyll a Concentrations: Southeastern Louisiana, Nan D. Walker, Adele Hammack, and Soe Myint, November 2000.]

4.3.4 Ground Truthing

Ground truthing is a process of comparing and correlating satellite data to actual field measurements. Ground truthing of sea temperatures in the Jefferson Parish project showed very similar results when comparing satellite and field measurements of surface sea temperatures taken at the eight sampling points shown in Figure 3.7. The linear regression of the temperature data-sets using 173 data points show a strong statistical linear correlation with an R^2 of 0.951. However, the satellite reflectance values, when compared to YSI turbidity field measurements, were not very similar (R^2 = 0.43). The differences are thought to result from several factors. For example, the satellite reflectance measurements were made at 580-680 nm and are related to light reflected from near the water surface by suspended material in the water column. The YSI probe measures backscatter from particles suspended in the water column (4 feet below the surface) in the 830-890 nm region. Other factors, which affect the satellite reflectances and YSI backscatter results, include the concentration of inorganic and organic material, type of inorganic sediment (clay, silt, and sand), and additional pigments (e.g., from other chlorophyll and colored dissolved organic matter).

[Source: EMPACT 1st Year Report, Satellite Remote Sensing of Surface Water Temperature, Surface Reflectance, and Chlorophyll a Concentrations: Southeastern Louisiana, Nan D. Walker, Adele Hammack, and Soe Myint, November 2000.]

The mapping of chlorophyll *a* with SeaWiFS in coastal regions requires extensive collection of water samples to validate the technique and develop regional algorithms if necessary. The SeaWiFS radiance data is collected in 6 visible channels which can be used to map suspended solids, suspended sediments and chlorophyll *a*. On April 26, 2000, a SeaWiFS ground truth experiment was conducted in Barataria Bay and the coastal ocean, seaward of the bay. The satellite-derived chlorophyll *a* estimates using SeaWiFS were very similar to the chlorophyll *a* concentrations of the field samples.

A cubic regression model yielded the best relationships between field and satellite data, with a an R^2 of 0.92. However, the correlation was not as strong for chlorophyll values measured in Lakes Cataouche and Salvador, probably due to higher concentration of colored dissolved organic matter.

Turbidity was estimated from two SeaWiFS channels (555 nm and 670 nm). Regression analysis revealed that the 670 nm channel yielded the highest statistical relationship between the satellite and field measurements. (R^2 of 0.84 - nonlinear power relationship).

[Source: EMPACT 1st Year Report, Satellite Remote Sensing of Surface Water Temperature, Surface Reflectance, and Chlorophyll a Concentrations: Southeastern Louisiana, Nan D. Walker, Adele Hammack, and Soe Myint, November 2000.]

4.3.5 Data Transfer

As discussed earlier, the LSU ESL receives the NOAA AVHRR and SeaWiFS satellite data. Through a sequence of processing steps computations are made of surface temperature, surface reflecance and chlorphyll a. GIF images are posted on the LSU Web site in quasi real-time.

The GSFC EOS DAAC is responsible for the distribution of SeaWiFS data to all approved SeaWiFS data users.

4.3.6 Data Management

The NOAA AVHRR temperature and reflective imagery is provided on the LSU Web site usually the same day the data are received (i.e., almost real-time). Dr. Walker provides interpretive text with the imagery to assist the public in understanding the image pattern.

The GSFC EOS DAAC is responsible for permanently archiving and distributing the SeaWiFS data. LSU processes the SeaWiFS data as they are received; however because the data have a 14 day embargo period, they are not available in real-time nor are they posted on the LSU Web site.

4.4 Water Quality Field Sampling

Water samples for lab analysis are taken weekly from eight stations in Lake Salvador and Lake Cataouche. (Cataouche is a smaller lake to the north of Salvador (Figure 3.7). Both lie in the direct flow path of the Davis Pond Diversion.). Collection stations were chosen by Dr. Chris Swarzenski, a scientist with USGS, who has been doing marsh grass research in the area for the past 15 years to compliment and augment monthly monitoring in the area by others (USACE, Louisiana Department of Natural Resources, United States Park Service, and Turner).

Additionally samples are taken from the upper Barataria Basin to the Gulf of Mexico during two separate collection dates during the summer months when conditions are most conducive to phytoplankton growth. These weekly and special event samples are to "surface truth" the satellite reflectance measurements and to relate the digital measurements of turbidity and fluorescence to suspended solids and chlorophyll *a*. These water samples provide baseline information on variations in water quality in the study region before the opening of the Davis Pond Diversion.

4.4.1 Water Quality Analyses

The LSU-CEI laboratory analyzes the field water samples for the following parameters: (1) water salinity; (2) pigments (chlorophyll *a* and phaeophytin a); (3) suspended load (sediment and organic); (4) carbon (total, inorganic, and total organic carbon); and (5) nutrients (Ammonium, Nitrate, Nitrite, Phosphate, and Silicate). The analytical techniques used to conduct the water quality analyses are described below.

Salinity/Conductivity

Salinity or conductivity of each sample is measured upon return to the laboratory using a Haake-Buchler Digital Chloridimeter® [http://www.analyticon.com/manurefy.html]. This device measures the amount of chloride in the sample by titrating it with silver. Salinity measurements are necessary to interpret the circulation and bulk impacts of the freshwater diversion.

pH

A Corning Model pH-30 waterproof pH meter is used to measure pH of the samples upon return to the laboratory [http://www.scienceproducts.corning.com]. The pH measurements are necessary to convert the total carbon dioxide measurements to alkalinity.

Chlorophyl *a* and Pheo-Pigments

Chlorophyll *a* containing plankton are concentrated from a volume of water by filtering at a low vacuum through a glass fiber filter (GFF). The pigments are extracted from the phytoplankton using a solution of 60% Acetone and 40% dimethyl sulfoxide (DMSO). The samples are allowed to steep for 2 to 24 hours (maximum) to extract the chlorophyll *a*. The samples are then centrifuged to clarify the solution. The fluorescence is then measured before and after acidification with 0.1 N HCl. The fluorescence readings are then used to calculate the concentration (in μg/l) of chlorophyll *a* and pheophytin *a* in the sample extract. This procedure is a modification of EPA method 445.0 (Arar and Collins 1992) in which DMSO is used in lieu of grinding for extraction of the pigments.

Suspended Load

The suspended load is determined by filtering a known volume of water through a combusted (550 C) and pre-weighed glass fiber filter (Whatman Type GF/F or equivalent). The filters are dried (at 60 C) then re-weighed to determine total suspended load in mg/l. The filters are then combusted at 550 C, cooled, then re-weighed to determine organic suspended load (APHA, 1992). The sediment or non-organic suspended load is determined by subtracting the organic suspended load from the total suspended load.

Carbon

Total carbon (TC) is measured by employing High Temperature Catalytic Oxidation (HTCO) using a Shimadzu® TOC-5000A analyzer [http://www.ssi.shimadzu.com]. The machine operates by combusting the water sample (at 680 centigrade) in a combustion tube filled with a platinum-alumina catalyst. The carbon in the sample is combusted to CO_2, which is detected by a non-dispersive infrared gas analyzer (NDIR) that measures the total amount of carbon in the sample. Inorganic carbon (IC) is analyzed by first treating the sample with phosphoric acid (to remove organic carbon) and then performing the above analysis to obtain the total amount if inorganic carbon in the sample. Total organic carbon (TOC) is obtained by subtracting the IC value from the TC value.

Nutrients

The water samples are analyzed for nutrients with a Technicon Auto-Analyzer II [http://www.labequip.com] using the methods listed in Table 4.5 for each nutrient:

Table 4.5. Methods and Detection Limits for Nutrient Analyses

Nutrient Limit	Method	Detection
Nitrate-Nitrite	EPA Method 353.2	0.05 mg/l
Nitrite	EPA Method 353.2	0.05 mg/l
Ammonia	EPA Method 350.1	0.01 mg/l
Silicate	Technicon Method 186-72W/B	0.03 mg/l
Phosphorus	EPA Method 365.2	0.01 mg/l

4.4.2 Phytoplankton Identification

Water samples are also sent to Louisiana University Marine Observatory Consortium (LUMCON) where the harmful algal species present in the sample are identified by Dr. Quay Dortch. The Gulf of Mexico Program is currently providing funds to support this research.

Prior experience in counting phytoplankton in Louisiana coastal waters shows that the phytoplankton range in size from 1 μ to greater than 100 μ with the tiny phytoplankton often dominating the biomass. Traditional methods of counting phytoplankton have missed or underestimated these small phytoplankton, whereas the more recently developed epifluroescence methods can be used to count both small and large phytoplankton. Table 4.6 shows common phytoplankton groups counted in each size fraction. Methods other than the epifluroescence method, such as differential interference contrast (DIC) or scanning electron microscope (SEM), can also be used for identification when necessary.

The method for preserving and counting phytoplankton is adapted from Murphy and Haugen (1985), Shapiro and Haugen (1988), and Shapiro et al. (1989). In this method, one hundred milliliters of seawater are preserved with 50% glutaraldehyde to a final concentration of 0.5% (by volume) and refrigerated until samples are processed. One aliquot of sample is filtered through a 3 μm polycarbonate filter and onto a 0.2 μm polycarbonate filter without prior staining. The 3 μm filter is discarded and the 0.2 μm filter retained (0.2 to 3 μm size fraction). Another aliquot of sample is filtered through an 8 μm polycarbonate filter and then a 3 μm filter; both filters are retained (3 to 8 and >8 μm size fractions). Before filtration this aliquot is made up to 25 ml with filtered water of approximately the same salinity and stained with 0.05 ml proflavine monohydrochloride (Sigma P-4646, 1.5 g/liter in distilled, deionized water). If possible, all samples are filtered without vacuum, but if necessary, <100 mm vacuum is applied. All filters are transferred to slides and mounted with low fluorescence, low RFA

Table 4.6. Common Phytoplankton Groups Counted in each Size Fraction

Size	Phytoplankton Groups
0.2-3 µm	Coccoid cyanobacteria -- mostly Synechococcus Autotrophic eukaryotes Heterotrophic eukaryotes
3-8 µm	Photosynthetic flagellates and non-flagellates Heterotrophic flagellates and non-flagellates Cryptomonads Athecate dinoflagellates Diatoms Coccoid cyanobacteria
> 8 µm Diatoms	Dinoflagellates Ciliates Cryptomonads Colonial cyanobacteria Colonial, freshwater chlorophytes Coccoid cyanobacteria [1]

Many coccoid cyanobacteria occur in aggregates, especially when suspended particulate matter concentrations are high, which do not break up during size fractionation.

epi-fluorescence microscope [http://www.olympus.co.jp] with blue and green excitation (excitation filters BP-490 and BP-545, barrier filters O-515 and O-590, and dichromatic mirrors DM500 and DM580, respectively). The 0.2 and 3 µm pore size filters are counted immediately at 1000x. The 8 µm pore size filters are stored frozen and counted as soon as possible. Three different counts are made on the 8 µm filters, using different magnification and counting different areas of the filter, in order to adequately count small, abundant organisms, as well as large, rarer organisms. To avoid counting an organism more than once they are separated according to length. Phytoplankton is identified to the nearest possible taxon and the previous table describes the types of organisms usually observed in each size fraction. It is possible for some groupings of taxa and even individual species, to be present in more than one size fraction, if the size of colonies or individuals varies considerably or if they occurred both singly and in aggregates of sediment, organic matter and cells. The 0.2 and 3 µm filters are discarded after counting, because they quickly become uncountable; 8 µm filters are archived frozen at Louisiana Universities Marine Consortium.

4.4.3 Data Transfer and Management

The personnel collecting the water samples complete a field documentation form, of which one copy is kept on file by Jefferson Parish and one copy accompanies the samples to the lab. These water samples are delivered to the LSU-CEI laboratory within 6 hours of collection and are stored on ice or in a refrigerator until analyzed for corruptible analytes. The LSU-CEI laboratory has existing QA/QC plan approved under EPA project X-9996097-01. The processing for Chlorophyll *a* begins within 12 hours of sample delivery, and usually within 1 hour. The dissolved nutrient samples are stored frozen until analysis, usually within 2-4 weeks (sample analysis is more economical if done in batches of >50 samples).

Sub-samples of the water samples are sent to LUMCON immediately after sample collection for identification of harmful algal species. The Gulf of Mexico Program is currently providing funds to support this research. Project funds are used to interpret this data set and make it available to the public via the Internet; interpretive text is written or reviewed by Dr. Dortch.

LSU-CEI provides quarterly reports of all data (with allowances for a one month delay in processing and QA and QC) to the project manager at Jefferson Parish. Graphical summaries of each parameter, averaged for each lake, are updated within one week of laboratory analysis, but are subject to subsequent QA/QC procedures. Monthly graphics of key parameters are sent to the EMPACT manager for Jefferson Parish. A tabular summary of samples received, status and completion are maintained as part of a routine chain-of-custody procedure. Data are also presented on an LSU Web page linked to the Jefferson Parish EMPACT home page.

Jefferson Parish disseminates the monthly graphics of key parameters to the Jefferson Parish Marine Fisheries Advisory Board, the Davis Pond Freshwater Diversion Advisory Committee, Louisiana Department of Health and Hospitals and other stakeholders as requested, for their review and feedback.

Plots of the weekly field water sampling data from August 19, 1999 through August 17, 2000 are available on the LSU-CEI Web site at http://its.ocs.lsu.edu/guests/ceilc/.

The EPA is in the planning stages to make such data available through their EMPACT website [http://www.epa.gov/empact]. Currently, the EMPACT website has a link to the Jefferson Parish website.